Electromagnetic Wave Absorbers Prepared with Alnico Magnets

Jae-Man Song[1] · Dong-Il Kim[2] · Jeung-Hyun Choi[2] · Jae-Hyun Jeung[2]

Abstract

We compared electromagnetic(EM) wave absorption properties between Alnico magnet (A) and (B) with different magnetic properties. Also, we investigated the effect of carbon, thickness of absorbers, and Alnico contents on EM wave absorption, and clarified the relation between Alnico content and central frequency.

Key words : Alnico Magnet, Electromagnetic Wave Absorption, Different Magnetic Property, Sheet Type.

Ⅰ. Introduction

EM wave absorbers are used to protect EM machines, such as personal communication and wireless LAN systems, from unwanted EM wave radiations. Soft ferrites, such as Mn-Zn and Ni-Zn ferrites, are important materials as microwave absorbers because of their high magnetic loss, which contributes to the EM wave absorption[1],[2]. However, the magnetic loss of soft ferrites decreases quickly in the GHz range, so it is impossible to expect EM wave absorbers made with soft ferrites to show great absorption properties at GHz frequencies. Satoshi et al.[2] and Verman et al.[3] investigated microwave absorption on hard ferrite, such as Sr and Ba ferrites, because they show high magnetic loss in the GHz range and revealed that Ba and Sr ferrites are useful materials for EM wave absorbers in the GHz range.

When we consider the problem of the natural environment and resources, it is good to use recycled magnets. Already, we have studied the EM wave properties of EM wave absorbers prepared with recycled Mn-Zn and Ba ferrites[1],[4]~[7]. In the studies, we showed that recycled magnets could be useful materials for EM wave absorbers.

In addition to developing advanced EM wave absorbers with well known soft and hard magnetic materials, such as Mn-Zn, Ni-Zn, Ba, and Sr ferrites, it is important to develop new materials for EM wave absorbers. In the previous study, we suggested newly Alnico magnets are good materials as a new EM wave absorbers[7]. However, the reports on microwave absorbers prepared with Alnico magnets are very rare. It is not reported to compare EM wave absorption properties between Alnico magnets with different magnetic properties.

In this paper, we compare EM wave absorption properties between Alnico magnet (A) and (B), which have different magnetic properties. Also, we investigated the relation between Alnico content and central frequency. We prepared sheet-type absorbers with recycled Alnico magnets considering the problem of natural resource and environment.

Ⅱ. Sample Preparation and Measurements

2-1 Sample Preparation

In this research, we used recycled Alnico magnet (A) with magnetic properties of residual magnetic induction (Br)=0.65 T, coercivity (Hc)=45 kA/m, and maximum magnetic energy (BH)max=11 kJ/m^3, and recycled Alnico magnet (B) with magnetic properties of Br=0.87 T, Hc=125 kA/m, and (BH)max=45 kJ/m^3 as starting materials for preparing sheet-type absorbers. The magnets were smashed with a hammer, pulverized with a vibration mill, and mixed with silicon binders and/or carbon by using an open roller. The open roller's surface temperature was uniform during sample preparation because the surface temperature affects the EM wave properties of sheet type absorbers[5]. The detailed preparation conditions for Alnico magnet absorbers are listed in Fig. 1.

2-2 Sample Measurements

For the investigation of the EM wave absorption properties of the samples, the prepared sheet-type absorbers were punched into a toroidal shape with an inner diameter of 3.05 mm and an outer diameter of 6.95 mm. The punched samples were putted into sample holder to investigate the EM wave absorption as shown in

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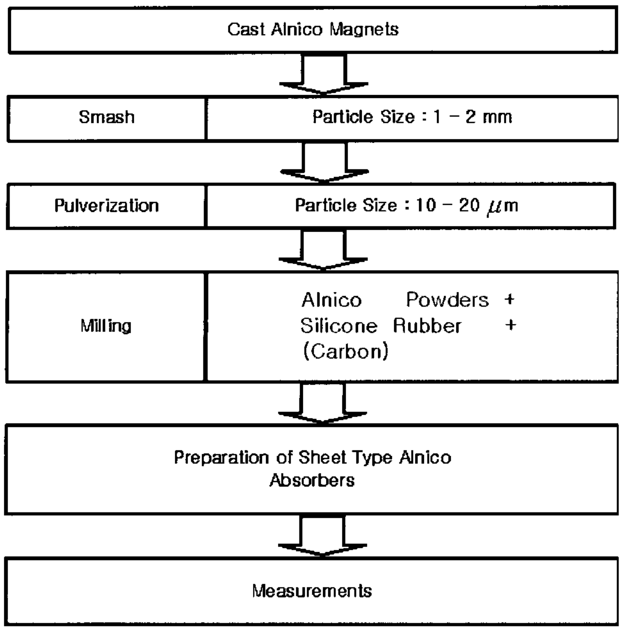


Fig. 1. Preparation of sheet-type Alnico absorbers.

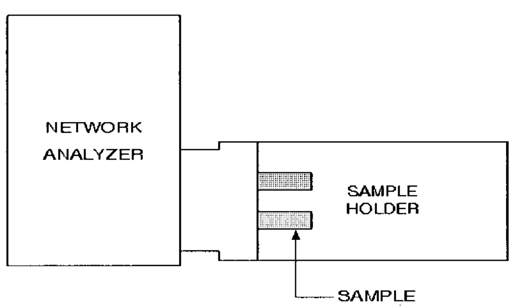


Fig. 2. Measurement system for the reflection coefficient.

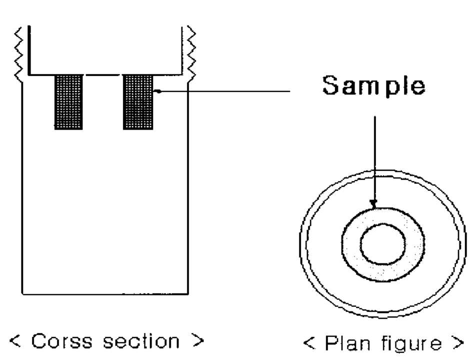
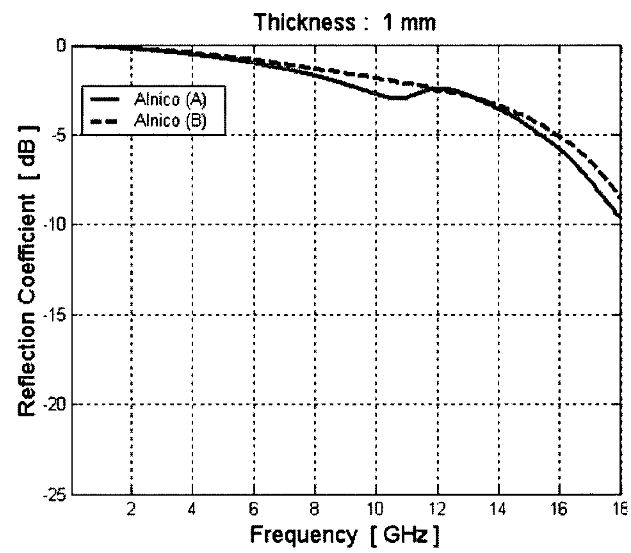


Fig. 3. Sample holder.

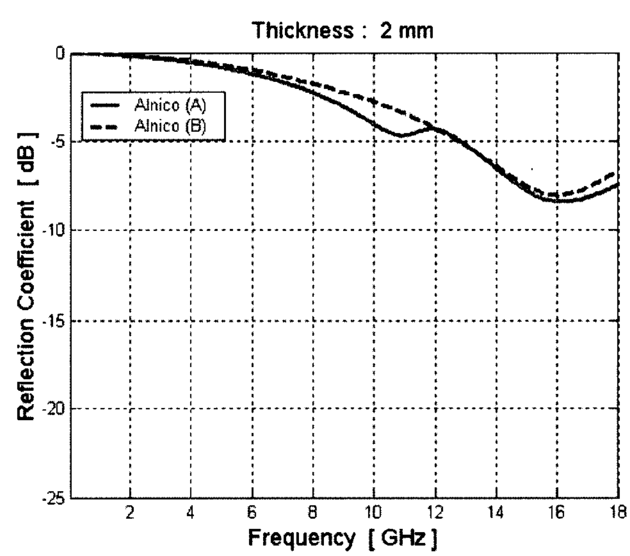
Fig 3. The absorption properties of the samples were investigated with a HP-8753D network analyzer. Figs. 2 and 3 are diagrams of the measurement system used for the reflection coefficient and the sample holder, respectively.

III. Results and Discussion

We compared the EM wave absorption properties between Alnico magnet (A) and Alnico magnet (B) for the sample thickness of 1 mm and 2 mm. Fig. 4 shows that the EM wave absorption properties are almost same in two samples even though they have different residual flux density, coercivity, and maximum energy product. Thus, we conclude that the magnetic properties of residual flux density, coercivity, and maximum energy product in a Alnico magnet do not affect strongly to EM wave absorption property.

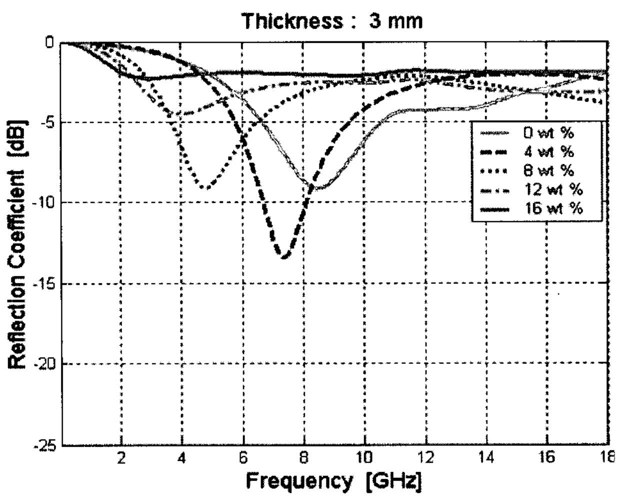


(a) Alnico : Silicone rubber = 50 : 50 wt%

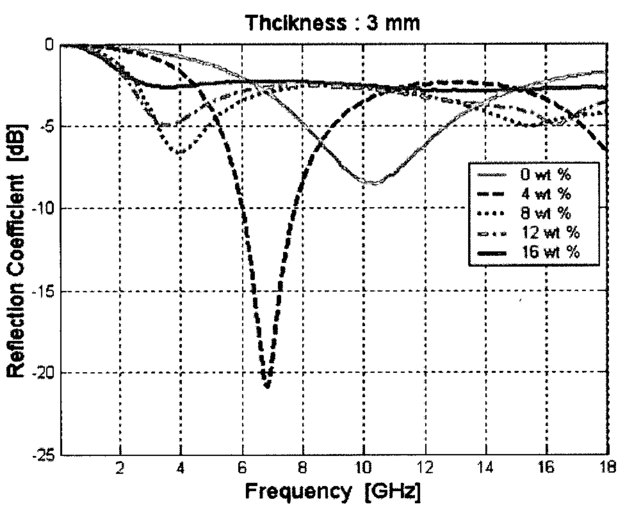


(b) Alnico : Silicone rubber = 50 : 50 wt%

Fig. 4. Reflection coefficient as a function of frequency for Alnico magnet (A) and Alnico magnet (B). (a) is sample thickness of 1 mm and (b) is sample thickness of 2 mm.



(a) Alnico magnet (A)

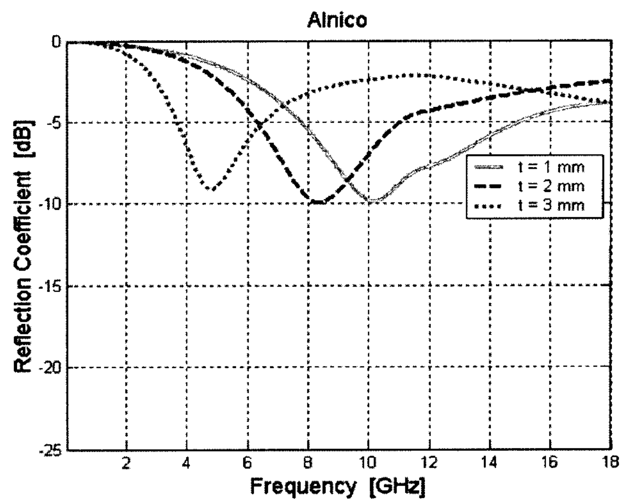


(b) Alnico magnet (B)

Fig. 5. Reflection coefficient as a function of frequency for samples of 3 mm-thickness with different carbon contents.

Many researchers have revealed that carbon is a very useful material for increasing the EM wave absorption properties because of their dielectric loss[8]. Thus, we investigated the effect of carbon in Alnico magnet absorbers on the EM wave absorption properties. Fig. 5 shows that the reflection coefficient in Alnico magnets depends on strongly by carbon amount and the central frequency decrease with increasing carbon content in both of Alnico magnet (A) and (B). Therefore, we conclude that the carbon is very useful material for increasing microwave absorption properties in Alnico magnets.

Fig. 6 shows that the central frequency decreases with increasing sample thickness. This phenomenon is consistent with the equation



(a) Alnico magnet (A)

Fig. 6. Reflection coefficient as a function of frequency for Alnico magnets (A) with different thickness.

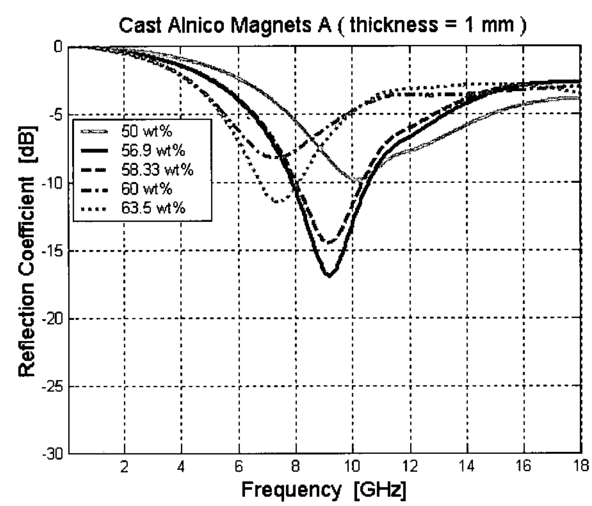
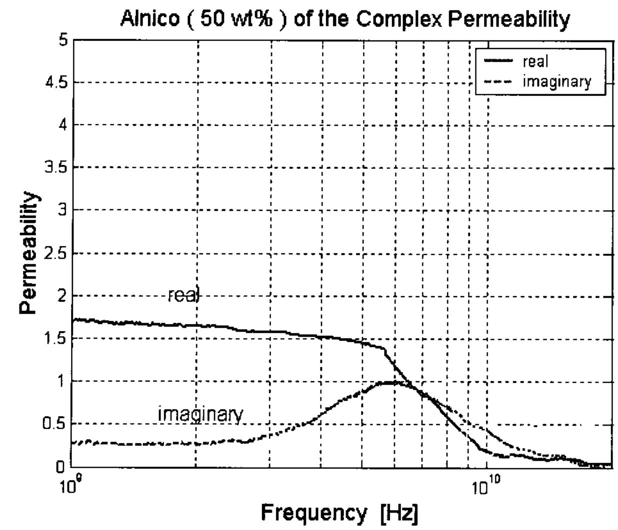


Fig. 7. Reflection coefficient as a function of frequency for Alnico magnet absorbers with different Alnico contents.

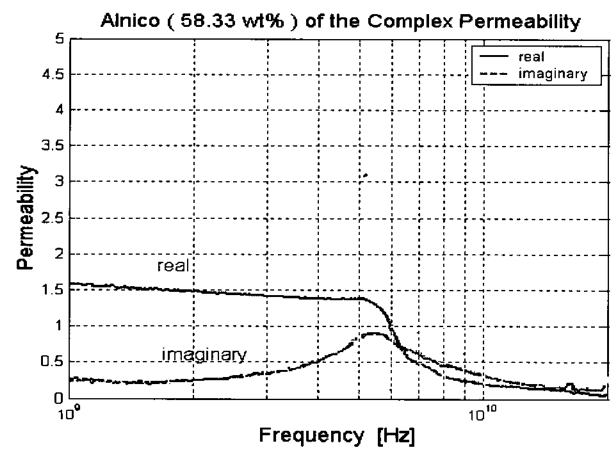
$$d=c/2\pi\mu''f$$

where c, d , and f are the velocity of light, the sample thickness, and the central frequency, respectively[8].

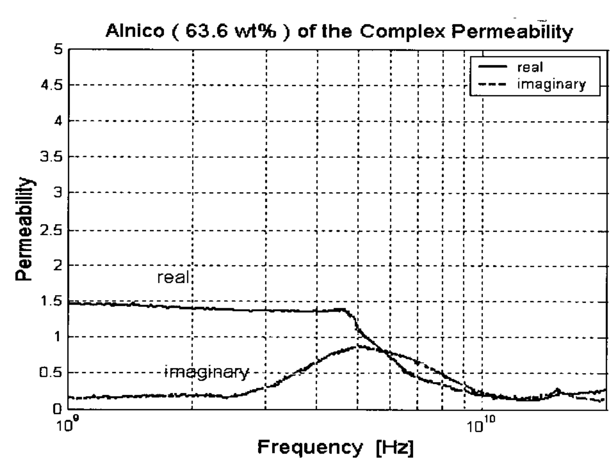
Fig. 7 shows the reflection coefficient as a function of frequency for the samples containing 50 wt%, 58 wt%, and 63 wt% of Alnico. Central frequency shifts toward lower frequency with increasing Alnico contents. To clarify this phenomenon, we investigated permeabilities, and show the result in Fig. 8. The point of tan δ=1 shifts toward lower frequency with increasing Alnico contents. The EM wave absorption of ferrites is related with magnetic loss tan δ, and the magnetic loss is strong for tan $\delta>1$[8]. From the above result, we conclude that the



(a) 50 wt%



(b) 58 wt%



(c) 63 wt%

Fig. 8. Complex permeability as a function of frequency for Alnico magnet absorbers with different Alnico contents.

decreasing of central frequency with increasing Alnico contents is because the frequency of tan δ=1 decreases with increasing Alnico contents, and it is possible to control central frequency by Alnico content.

Ⅳ. Conclusion

We used recycled Alnico magnets as a sheet-type EM wave absorber and compared EM wave absorption properties between Alnico magnet (A) and (B) with different magnetic properties of coercivity, residual flux density, and maximum energy product. We confirmed, even though they had different magnetic properties before pulverization, the two Alnico magnets had almost same EM wave absorption properties. Carbon in Alnico magnet absorbers affect strongly to EM wave absorption properties, and central frequency shits toward lower frequency with increasing carbon content. The EM wave absorption peak shifts toward lower frequency with increasing Alnico contents, which relates with the frequency of tan δ=1.

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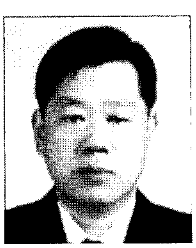

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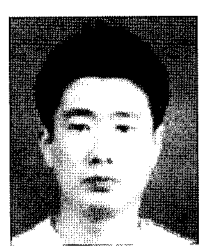

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